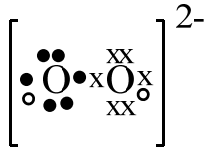
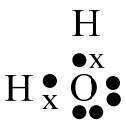
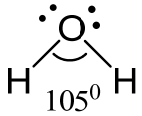
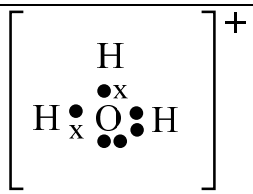
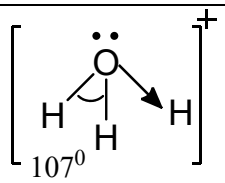
Answers to Practice Questions (Long)

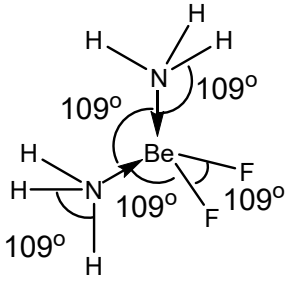
10. (a) 

(b) H_3O^+ and Cl^- ions formed

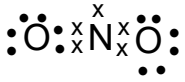
Species	Bond angle	No. of e^- pairs	No of bond pairs	No. of lone pairs	Shape
H_2O	105°	4	**2**	**2**	bent
H_3O^+	107°	4	**3**	**1**	trigonal pyramidal
Lone pair – lone pair repulsion > lone pair – bond pair repulsion > bond pair – bond pair repulsion $H_2O \rightarrow H_3O^+$ One lone pair becomes a bond pair through co-ordinate bonding ⇒ No lone pair – lone pair repulsion in H_3O^+. ∴this results in a greater bond angle.					

	Dot-and-cross	Structural formula
H_2O		
H_3O^+		

(c) $BeF_2 \cdot 2NH_3$ adduct



tetrahedral wrt to both Be and N in the product

11. (a)  

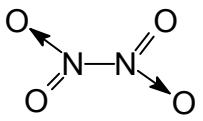
(b) Both molecules have three regions of electron density and thus their electron-pair geometry is trigonal planar.

- Electron pairs exert greater repulsion than an unpaired electron. As a result, the bond pair – bond pair repulsion > bond pair – unpaired electron repulsion in NO_2. Thus, the bond angle in NO_2 would be greater than 120°, e.g. 130° (The actual bond angle is 134°. Acceptable answers are any value from 120° to 170°).
- Lone pair – bond pair repulsion > bond pair – bond pair repulsion. For O_3, the lone pair of electrons on the central O exert greater repulsion than the bond pairs of electrons in O-O

bond. Thus, the bond angle in O_3 would be less than 120°, e.g. 118° (The actual bond angle is 117°. Acceptable answers are from 110° to 120°).

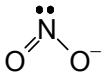
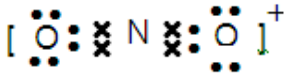
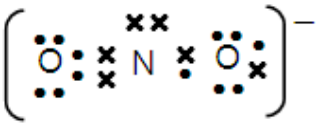
Teachers, pls use this question as a teaching point: A lone pair or a bond pair exerts **greater repulsion** than a **single** electron as the repulsion exerted by 2 electrons is greater than 1 electron.

(c) NO_2 has an **odd** number of electrons i.e. there is an unpaired electron in N. **Dimerisation** only involves the formation of N–N covalent bond which releases energy to the surroundings. The energy of the products is less than that of the reactants, hence the reaction is feasible.



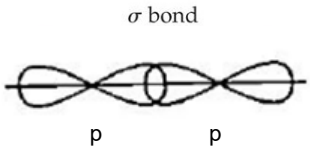
(Please note that there are other considerations that will determine the feasibility of reactions. They will be discussed in Lecture 5 – Energetics.)

(d)

	NO_2^+ $O{=}N{=}O^+$	**NO_2^-** 
Dot-and-cross diagram		
No. of electron densities around N:	2	3
To minimise electrostatic repulsion, the electron–pair geometries are:	linear	trigonal planar
Number of lone pairs	0	1
Molecular shape is	linear	bent

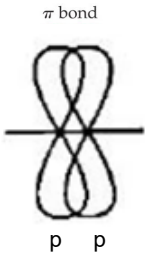
12 (a)(i) Phosgene, $CCl_2C{=}O$, has <u>3 bond pairs and 0 lone pairs</u> of electrons around the central C atom. To minimize electronic repulsion between the bond pairs, the shape of the phosgene molecule is <u>trigonal planar</u>.

(ii) σ (sigma) bond



<u>head-on</u> overlap of p orbitals
(show head-on overlap of either s/p orbitals)

π (pi) bond



<u>side-to-side</u> overlap of p-orbitals

Note: it is necessary to label the orbitals and state the type of overlap

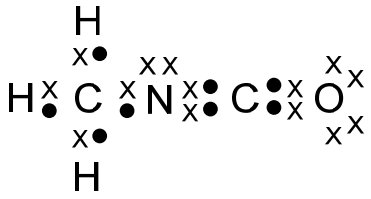
(b)(i) Electronegativity is the relative ability of an atom in a molecule to attract bonding/shared electrons.

(ii) Phosgene molecules have intermolecular instantaneous dipole-induced dipole (id-id) and permanent dipole-permanent dipole (pd-pd) interactions.

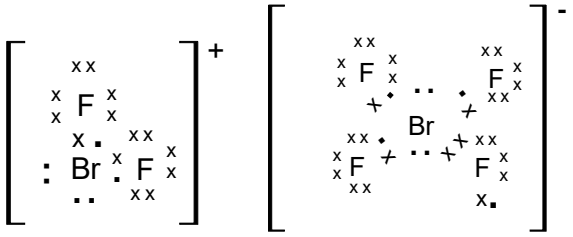
Electrons are constantly moving and at any given moment, the electron density of a phosgene molecule can be unsymmetrical, resulting in an instantaneous dipole, which induces a short-lived dipole in a neighbouring phosgene molecule, hence resulting in id-id interactions.

Phosgene molecules are polar with permanent dipoles in their structures. Pd-pd interactions arise due to the electrostatic attraction between the partial positive end of one phosgene molecule and the partial negative end of the other phosgene molecule.

(c)

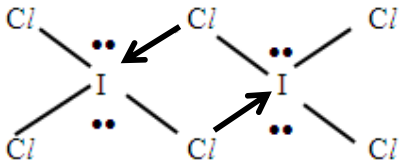


13 (a)



Bond angle in BrF_2^+: 105° (values between 90° and 107° are accepted)

(b)

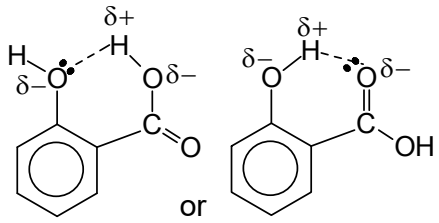


(c) Chlorine is a smaller atom compared to iodine, so it cannot 'pack' as many fluorine atoms around itself, due to repulsion of electron clouds between the F atoms / overcrowding of the F atoms/ steric factors between the F atoms.

14. (a) H_2O, NH_3 and HF all have intermolecular hydrogen bonding. However, H_2O can form on average 2 hydrogen bonds per molecule whereas NH_3 and HF can only form 1 hydrogen bond per molecule. Therefore, more energy is needed to overcome the more extensive hydrogen bonding between water molecules, resulting in its highest boiling point.

As F is more electronegative than N, the hydrogen bond between HF molecules is *stronger* than that between NH_3 due to the greater δ- formed on F and δ+ on H atoms on HF molecule. More energy is therefore needed to overcome the hydrogen bonds between HF molecules, resulting in HF having a higher boiling point than NH_3.

(b) Due to the close proximity of the –OH to the –COOH groups, 2-hydroxybenzoic acid forms intramolecular hydrogen bonding as shown in the diagram on the right. Thus, it has less sites available for the formation of intermolecular hydrogen bonding with water molecules.



- - - - represents intramolecular H bond.

Hence 2-hydroxybenzoic acid forms less extensive intermolecular hydrogen bonding with water molecules compared to 4-hydroxybenzoic acid, resulting in lower solubility in water.

15. (a) Both compounds exist in giant ionic lattices. Melting involves overcoming the strong electrostatic forces of attraction between the cations and anions. This strength of ionic attraction is approximated by the magnitude of lattice energy, $|L.E.| \propto |(q_+q_-) / (r_+ + r_-)|$.

Since Ca^{2+} and O^{2-} are both doubly-charged compared to the singly-charged Na^+ and Cl^-, the magnitude of L.E. for CaO is greater than that of NaCl (OR L.E. of CaO is more exothermic than that of NaCl) and the ionic bond in CaO is stronger than that in NaCl. Hence CaO has a higher melting point.

(b) They are covalent substances with simple molecular structures.

$SiCl_4$ is a non-polar molecule which forms weak instantaneous dipole–induced dipole interactions only.

PCl_3 is a polar molecule which forms slightly stronger permanent dipole–permanent dipole and instantaneous dipole–induced dipole interactions. Hence the boiling point of PCl_3 is higher than $SiCl_4$ that of since more energy is required to overcome the intermolecular forces of attraction between PCl_3 molecules during boiling.

$SiBr_4$ is non-polar but it has a much larger electron cloud compared to PCl_3. A larger electron cloud is more easily polarised, hence, the intermolecular instantaneous dipole-induced dipole interactions found in $SiBr_4$ is significantly stronger than those found in PCl_3 which has a much smaller electron cloud. This results in the higher boiling point of $SiBr_4$, even though $SiBr_4$ does not have pd-pd interactions.